Synthèse d'article

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Drone-Based System for Localization of People Inside Buildings

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1 Introduction

1.1 State of the art

The localization of team members is an important asset in many operations conducted by firemen, police teams or military troops. The techniques for applying it on people outdoors are well known and widely applied. Usually, that kinds of localizing systems are composed of a monitoring station and several personal units. There are two main approaches to establish the positions of the users : the most popular assumes that the personal units calculate their own coordinates and transmit them to the monitoring station thanks to dead-reckoning systems (*DR*) and INS/GNSS (*Inertial Navigation System, Global Navigation Satellite System*) systems. The second one is based on radio signals transmitted by the personal units and calculations exclusively made in the monitoring station.

Those two approaches are not reliable for localizing personal units indoors with the localizing systems placed outside. Ultra-Wideband (*UWB*) radio is a promising technology which could solve this issue and has not yet been tested on the field for that kind of application.

1.2 Project's goals

The paper's experiment uses UWB radio to localize people inside buildings from outdoors. Such a device could help to localize personal units during interventions in order to coordinate complex team actions or run the evacuation of one of a team member in case of emergency for example.

1.3 Development of the project

The authors of the paper conceived a state-space model of a system able to localize people inside buildings from an outside location and an algorithm for estimate the users' positions. They also made simulations to evaluate the accuracy of the device.

1.4 Technical approach and contribution

The device is based on UAVs (*Unmanned Aerial Vehicles*) playing the role of the localizing units. Those drones use UWB radio to estimate the positions of the team members and the calculations are based on EKF (*Extended Kalman Filters*) equations composed of a linear dynamics model and a non-linear observation model written by the authors.

2 Global description of the system

The system is composed of a Monitoring Station (MS), a Localizing Unit (LU) installed on a multicopter (drone) and several Personal Units (PUs), one for each team member to be localized. The MS and LU are equipped in radio modems and are capable of two-directional exchange of data. The MS is composed of a computer with a special application, the multicopter remote controller and a local GNSS RTK (*Real Time Kinematic*) base station. It can pass RTK corrections to the LU and receive locations of team members from it.

Once the MS is deployed near the building and the team of people to be localized, equipped with the PUs, enters inside, the multicopter equipped with the LU starts to circulate around the area of interest. It can be remotely controlled from the MS or programmed to fly in autonomous mode and follow a predefined path.

3 Technical means and algorithms

The MS can be installed on a lite vehicle which can also carry the LU. The LU and all the PUs contain UWB radio ranging modules using Two-Way Time-of-FLight (TW-TOF) technique for accurate ranging. This technology has been chosen for its capacity to penetrate windows, wooden doors and thin walls, making it the most appropriate for such an issue.

The radio modules chosen for this study are the Pulson P440 from the Time Domain company. They have been chosen for their high frequency range (to 4.8 GHz) and their transmitted power of about 50 μW, and tested by the authors on a previous study. The operating range with a clear line of sight (CLOS) can reach 1 kilometer. Some new studies made for this paper proved that such two UWB modules can communicate informations even if they are separated by a thick shielding surface.

In real situation, it is expected that the ranging measurements calculated by the LU will be available only occasionnally, when the LU and a PU are separated by thin surfaces, windows or doors, as the visibility conditions might be complicated. A local GNSS RTK base station will be installed as a part of the MS equipment. Thanks to a GNSS receiver capable of incorporating RTK corrections sent from this base via a radio modem, the position of the LU will be calculated with an accuracy of a few centimeters.

The authors imagined different ways to calculate the users' positions. It can be realised on the board of the drone and then transmitted to the MS, or exclusively made inside the MS, which would estimate the PUs positions thanks to the ranging measurements and LU positions sent beforehand by the LU itself. The first option is preferred by the author as it makes the system more versatile and could permit the distribution of the data amongst the team members for different types of special operations, but that's an expensive choice as the LU must contain a more powerful processing unit so it can run the estimation algorithms.

The algorithm implemented in the LU is composed of parallely running EKF, one for each tracked PUs. Thanks to the separation of the different PUs data inside the LU processing unit and the unique adress of each UWB module, this system can efficiently treat each PUs separately.

The EKF equations are formulated thanks to the equations which describe the model of the system. This state-space model is composed of a linear dynamics model and a non-linear observation model. The dynamics model relies on several simplifying assumptions. For example, the team members are assumed to not move significantly during the process of establishing their positions, and the drone and the member of the team need to be considered on the same horizontal plan during this process so the algorithms can calculate positions in two dimensions only. Thanks to the Kalman Filters, some unknown parameters are treated as minor random disturbances in the equations. The non-linear observation model is so calculate on a two-dimensional plan and is designed to measure the distance between the LU and a PU.

Each one of the parallel EKF algorithm relies on the dynamics model to realize the time update whereas the measurement update is based on the non-linear observation model. Those two updates are realised recursively in the algorithm. The time update is realised regularly, whereas the measurement update is made at an irregular rate depending on the obstacles between the LU and the targeted PU.

4 Results of experiments

4.1 Test of the PulsON P440 modules

The radio modules PulsON P440, previously introduced in this synthesis, have been tested by the authors. In those tests, the Signal-to-Noise Ratio (SNR) of a received UWB signal has been evaluated, and its value depends on the distance between two modules but also on the type of material and the thickness of the obstacle between them. The conclusion of the testers is that the chosen technology is accurate enough to permit the deployment of the presented device in real situation. For example, even if a wall thick of 45 centimeters separates the modules, the transmission is made if there is less than 5 meters between them.

4.2 Simulation of the system

5 Limits of the project

6 Possible evolutions

7 Bibliography